7. OFF-LINE OPERATIONS

Before launch and during the operational phases of the mission, much of the FOT's effort centers on activities that support TRMM, but are not directly related to real-time operations. The broad categories of these off-line activities include mission planning, load generation, TDRS scheduling, performance and trend analysis, and DataBase maintenance. The main objective of these planning activities is to provide a safe, pre-planned operations approach of the observatory.

7.1 MISSION PLANNING

Mission planning describes the process of instrument and spacecraft activity coordination for the successful completion of mission objectives. Activity requests will be directed to the FOT. The FOT will make use of a MOC-provided Mission Planning Timeline function to coordinate approved instrument and spacecraft activities. A formatted report of the timeline will also be made available to TSDIS, NASDA/EOC via TSDIS, LaRC, MSFC, and the FDF. Mission planning will be performed on a daily basis, however, the TRMM Mission Planner will typically work Monday through Friday. Figure 7.1-1 provides a graphical illustration of the mission planning process for TRMM.

7.1.1 Inputs to Mission Planning

The primary inputs to the mission planning process are the Instrument activity requests, FDF provided planning aids, TDRS schedules, and spacecraft orbit and attitude maneuver plans. The TSDIS SOCC will provide activity requests for the rain instruments (PR, VIRS, and TMI), and the FOT will generate a Daily Activity Plan (DAP) containing directives/commands to perform spacecraft housekeeping activities, and to accomplish science objectives for the CERES and LIS instruments.

7.1.1.1 Instrument Mission Planning

Instrument mission planning will be performed for each instrument in order to achieve the TRMM science goals. CERES and LIS instrument activities will be planned by the FOT according to LaRC and MSFC direction. The PR, VIRS, and TMI instrument activities will be organized as activity requests, provided by the TSDIS SOCC and merged with the spacecraft, CERES, and LIS activities. Direction for PR activities will be provided to the SOCC by the NASDA EOC. Each
instrument facility (LaRC, MSFC, TSDIS SOCC, and NASDA EOC {via TSDIS}) will have access to planning aids and telemetry displays resident in the MOC. There will also exist a capability to browse planning aids or to initiate a transfer of the planning aid files. Certain reports and planning aids will be automatically transferred from the MOC to each facility at pre-arranged intervals. Transfer and browse agreements of these items will be documented in an Operations Agreement (OA) with each facility; LaRC, MSFC, and TSDIS.

7.1.1.1.1 CERES Command Inputs

LaRC will rely primarily on the FOT to operate the CERES instrument. The FOT will be responsible for planning and scheduling CERES command operations. CERES activities will be coordinated with other observatory activities via the Mission Planning Timeline. CERES instrument activities requiring command activity are as follows:

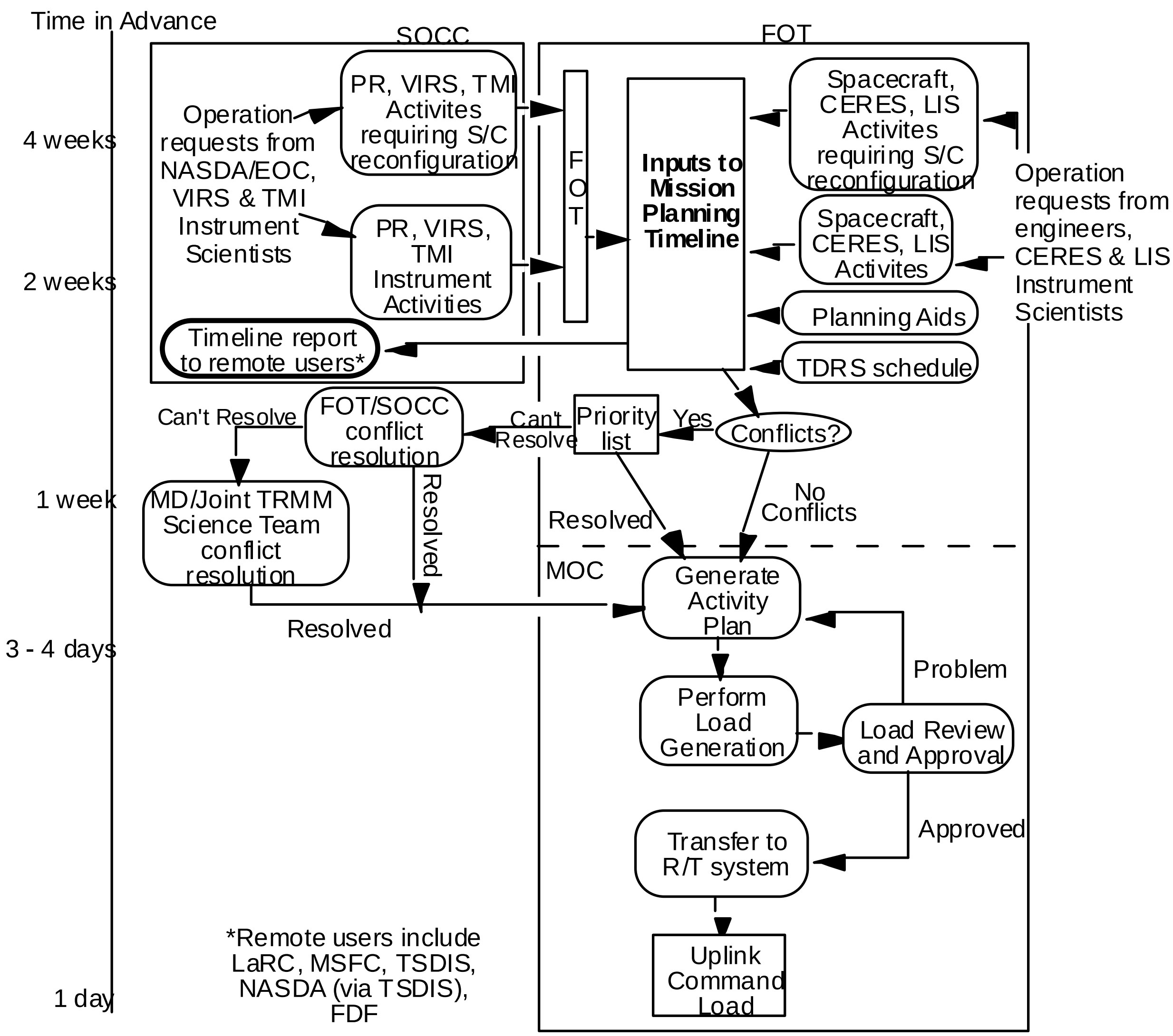


Figure 7.1-1 TRMM Mission Planning Process

a. Solar Calibration
b. Internal Calibration
c. Biaxial to Cross Track Scan Transition (switching instrument scan mode)
d. Short scan and Set Max. # of scans commanding (applicable only while in Biaxial Scan mode)
e. CERES operations while in Biaxial mode within ß = ± 20°
f. CERES configuration during spacecraft maneuvers
g. CERES Deep Space Calibration
h. CERES Safing concern at the end of the daily load

Solar and Internal calibrations will be performed every 2 weeks. The FOT will determine the time of the solar calibration by utilizing the azimuth/elevation planning aid file via the GSOC utility. The criteria for determining the time for a calibration is based on when the Sun elevation angle equals -11°. The corresponding time and azimuth angle will be selected and uplinked to the CERES instrument, prior to initiation of the solar calibration command. Both the azimuth angle and solar calibration commands will be incorporated into the daily command load, in addition to the command to initiate the internal calibration. Solar and internal calibrations will each take approximately 30 minutes to complete.

CERES mode changes will be quite frequent throughout the mission. CERES will operate in the Crosstrack mode every 2 out of 3 days, and in the Biaxial mode the third day. CERES requires no additional commanding while in the Crosstrack mode, except for reconfiguring to Contamination Safe mode during spacecraft yaw and Delta-V maneuvers. Switching to the Crosstrack mode will nominally require only 1 command to be placed into the daily command load.

Biaxial operations will be planned using both the Beta angle file and the CERES azimuth/elevation angle file. The Beta angle file will be used to determine what angles CERES will rotate between for that particular day (angles A and B). If the Beta angle will be greater than -20° and less than +20° (-20°<B<+20°) for that entire day, angles A and B should be set to 110° and 250° respectively. On the other hand, if the Beta angle will be less than -20° (B<-20°) or greater than +20° (B>+20°) then angles A and B should be set to 90° and 270° respectively. In addition, the CERES azimuth/elevation planning aid file will be used to determine when to place CERES into the short scan profile and when to initiate the normal scan profile. Figure 7.1-2 shows a plot of the Sun azimuth and elevation angles as viewed from the CERES instrument in the orbit reference coordinate frame during a typical TRMM orbit. Predicted values for TRMM will be generated by the GSOC utility in the MOC. The diagram indicates the points in the orbit where stored commands (normal scan, short scan, scan time-out) are executed to prevent the instrument detectors from directly scanning the Sun near Sunrise and Sunset. The scan time-out command sets the scan time-out parameter. The time-out parameter will be calculated by the following equation:

$$n \text{ (number of scans)} = \left(\frac{\text{time of next short scan - time of normal scan}}{\text{6.6 seconds/scan}}\right) + \text{delta \# scans}$$

A command to initiate a RTS which includes Safing commands for the CERES instrument will be included at the end of each day's command load in case the next day's command load is not uplinked to the spacecraft. CERES will be placed into Safe mode, with the detectors stowed to prevent possible damage to the instrument. The first command of each day's command load will stop the Safing RTS. Nominally, this will stop the RTS prior to any RTS commands executing.

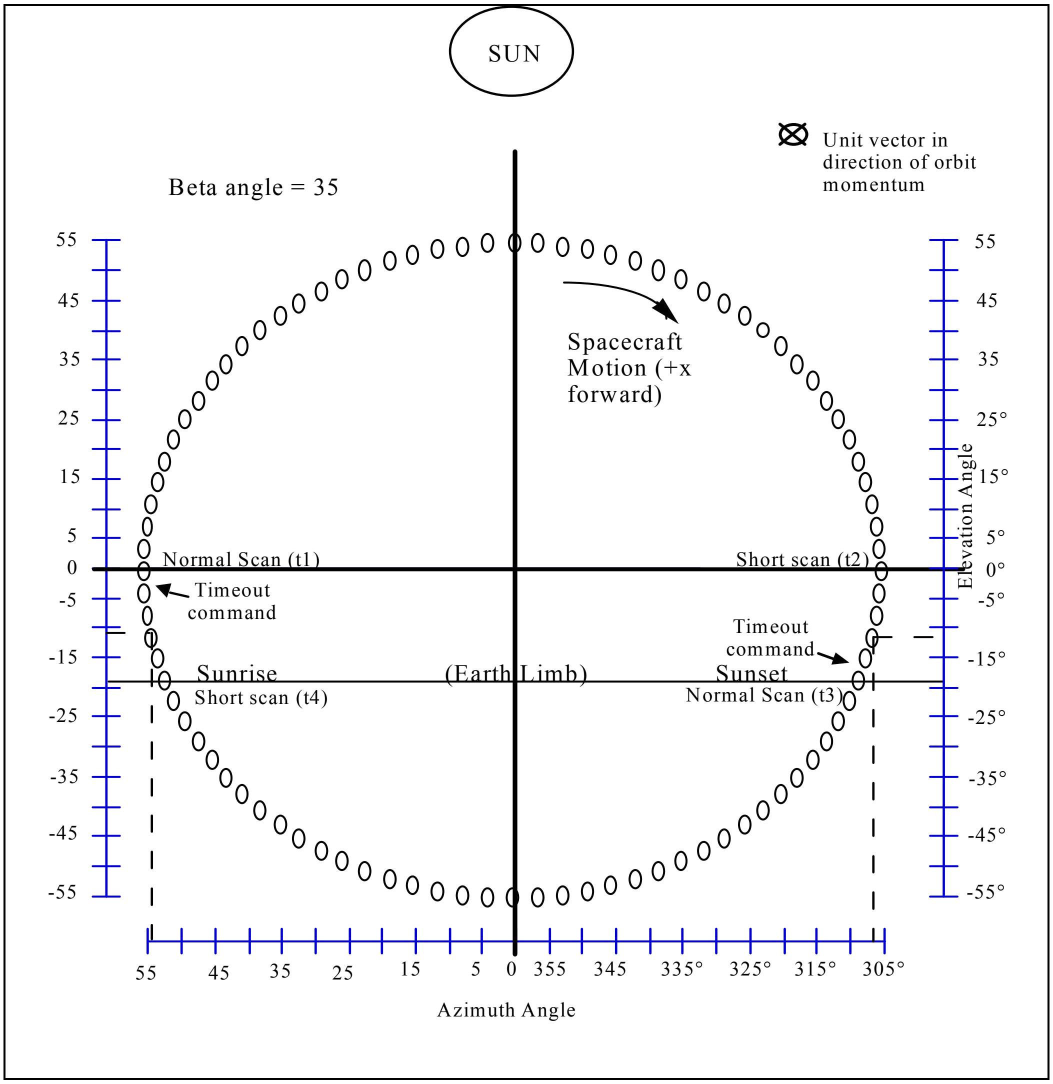


Figure 7.1-2 CERES Short Scan Scheduling Scenario

Requests for special CERES operations, such as the Deep Space Calibration, must be made by the CERES scientists at least 4 weeks in advance to allow for Project scientist approval, coordination with other observatory activities, and incorporation into the DAP. Once approved, the FOT will coordinate the calibration with all other instrument and spacecraft activities. The necessary commands will be placed into the daily spacecraft command load in order to perform the calibration.

7.1.1.1.2 LIS Command Inputs

The FOT will be responsible for scheduling LIS command operations. LIS instrument commanding will be somewhat frequent during instrument checkout and the first couple of months in Mission mode. Commanding will almost exclusively consist of changing the threshold values in the RTEP. Once data is analyzed and optimum threshold values are determined, LIS commanding will be minimal. LIS may require, however, additional commanding when participating in field campaigns.

The MSFC will rely primarily on the FOT to operate the LIS instrument. The LIS Science Computing Facility will also have access to planning aids in the MOC. LIS activities will be coordinated with other observatory activities via the MOC provided Mission Planning Timeline.

7.1.1.1.3 Rain Instruments Command Inputs

The SOCC will be the FOT's point of contact for instrument planning of the PR, VIRS, and TMI instruments activities. Instrument activities should be requested at least 2 weeks prior to the event week. Activities that require changes to the nominal spacecraft orientation, such as the PR Antenna Pattern Measurement, will require 4 weeks advance notification to the FOT, via the SOCC, for coordination with other instrument and spacecraft activities and for generation of special planning products. In addition, the SOCC must provide command parameter inputs to the FOT no later than 3 days prior to the scheduled activity, due to the load generation process. A timeline report will be provided to the SOCC to allow for coordination of PR, VIRS, and TMI activities with those of CERES, LIS, and the spacecraft .

In the event of an instrument conflict, the SOCC and FOT will attempt to resolve the issue. If the conflict can not be resolved, the TRMM Joint Science Team and MD will come to an agreed upon resolution . It should be noted that all required spacecraft maneuvers (180° yaw maneuver and Delta-V maneuver) will take precedence over an instrument activity request. Given the following activity priority guidelines, we believe that conflict resolution will not be necessary beyond the SOCC/FOT interface.

<u>Activity Priority Guidelines</u>
The following list defines the priority of activities for the TRMM observatory.

1. Any spacecraft anomaly (i.e. SafeHold, Low Power, etc.)
2. Instrument Safing
3. Recorder Playbacks
   - TDRS events where recorder playbacks are scheduled (all TDRS events) will take precedence over any event that would inhibit science data collection on the ground.
4. 180° yaw maneuver
5. Delta-V maneuver
6. Any rain instrument science activity, including anomaly troubleshooting for science performance.
   - This includes the PR Antenna Pattern Measurement (90° yaw)
7. Any CERES or LIS instrument science activity, including anomaly troubleshooting for science performance.
   - This includes the CERES Deep Space Calibration

According to the priority list, if an instrument anomaly occurs, NASA will take immediate action and NASDA will take emergency action for PR health, if other immediate action is not defined.

The EOC will have the primary responsibility for PR instrument planning. Planning aids will be accessible to the EOC, via the SOCC, for PR instrument planning. All PR operation requests will be checked by EOC to verify that they will not be within PR operations constraints before the activity time. The EOC will then send instrument activity requests and information to the SOCC, for transfer to the FOT, for incorporation into the DAP. Basic conflict resolution, if necessary, will be coordinated between the FOT and SOCC, with the EOC being represented by the SOCC personnel.

For the scheduling of PR external calibrations, the NASDA EOC will provide times corresponding to when the TRMM spacecraft will pass over the Active Radar Calibrator (ARC). External calibration commands will be placed into the daily command load, along with commands for an internal calibration.

Requests for the PR Antenna Pattern Measurement must be made by the PR scientists at least 4 weeks in advance to allow for coordination with other observatory activities and incorporation into the DAP. The FOT will coordinate the activity with all other instrument and spacecraft activities. The time and beam angle necessary for the measurement will be provided by the NASDA EOC, via the SOCC. The necessary commands will be placed into the daily spacecraft command load in order to perform the Antenna Pattern Measurement. During the planning process, NASDA EOC will receive verification of PR activities via the timeline report and, after load generation, via the Integrated Print report. For planning of both the external calibration and the antenna pattern measurements, NASDA EOC will request 2 time windows. The second window will only be scheduled as a backup in case of poor weather conditions during the first window opportunity.

VIRS and TMI activities will be scheduled by the Instrument Scientists using the appropriate MOC provided planning aids (Note: Planning aids will be distributed to the Instrument Scientists via the SOCC). VIRS solar calibrations will be scheduled according to when the Sun is predicted to be in the field of view of the VIRS solar calibration port. For solar calibrations, a command to open the calibrator door is required, and should be timed according to the Sun presence, as defined in the VIRS planning aids. A second command will be needed in order to close the door a set amount of time later.

The TMI instrument will not have any routine activity requests since TMI operates without interruption throughout the mission. No nominal commands will be required. Any requested activities for TMI will be incorporated only after an instrument activity request has been submitted.

7.1.1.2 FDF Planning Aids

FDF inputs to the mission planning process are Predicted Site Acquisition Tables (PSATs), User Antenna Views (UAVs), Beta Angle predictions, Maneuver Planning File and Maneuver Command File, and ephemerides for TRMM, COMETS, and up to six TDRSs. PSATs contain orbital events, such as spacecraft day and night, South Atlantic Anomaly (SAA) crossings, and ground station visibility periods. These events are used for the triggering of time-tagged commands, and for inclusion in various reports. The UAVs provide TDRS view periods (attitude dependent), and are used for nominal TDRS scheduling. Beta angle predictions are used to plan the 180° yaw maneuvers and CERES Biaxial scan modes, and the Maneuver Planning file is used for Delta-V maneuver planning and coordination with other long-term mission planning activities. The Maneuver Command File is used for ACS ATS load generation. Ephemeris data are used in modeling spacecraft attitude, which is required for constraint checking and for computing attitude-dependent events.

CERES Sun azimuth and elevation angle predictions and VIRS Solar Calibration predictions will be generated in the MOC, via the FDF provided Guide Star Occultation (GSOC) utility. The CERES Sun azimuth and elevation angle predictions will be generated autonomously upon receipt of the FDF provided ephemeris, Time Conversion Coefficients, and Solar/Lunar Prediction (SLP) files, and will be used to schedule CERES Solar Calibrations and solar avoidance commanding. The VIRS planning aids will be used to determine command times for VIRS Solar Calibrations. The FOT will be responsible for CERES Solar Calibration scheduling (as described in section 7.1.1.1.1). The VIRS planning products will be autonomously transferred to the TSDIS SOCC upon generation. The VIRS instrument scientist will perform VIRS Solar Calibration scheduling, and will provide the scheduled times to the FOT, via the SOCC, for incorporation into the appropriate DAP. The above planning aid files are described in Section 8.

7.1.1.3 TDRSS Schedule

The TDRS schedule is used to coordinate scheduled activities with real-time supports. Special activities (yaw maneuvers, orbit adjust maneuvers, etc...) may require modifications to the real-time TDRS schedule. In addition, the TDRS schedule is used in the load generation process for autonomously triggering AOS and LOS sequences. A detailed description of the TDRS scheduling process is provided in section 7.3.

7.1.1.4 Delta-V Maneuver Planning

The FDF will provide a 5 week Maneuver Planning file to the MOC. This planning file will be incorporated into the Mission Planning Timeline. The Maneuver Planning file contains the predicted burn times, number of burns required (1 or 2), and the planned spacecraft orientation (+X or -X). The Maneuver Planning file will be delivered weekly, and subsequent to each maneuver. A MOC generated report from the Mission Planning Timeline will be used by the remote instrument facilities to coordinate and schedule instrument activities around Delta-V maneuvers.

In addition to the Maneuver Planning file, the FDF will also provide a Maneuver Command file. The Maneuver Command file will include information required to construct the commands to be incorporated into an ACS SCP command load. No later than 24 hours prior to a burn execution time, FDF will transmit a Maneuver Command file to the MOC. As inputs to the Maneuver Command File, the FOT will provide trending of relative data to be used for computing the maneuver commands. This trending will be performed 24 hours before the maneuver command file is scheduled to be delivered. Trending will be done over a 1 orbit period (preferably an orbit around the same time as the planned maneuver time) and will include the following:

- Tank 1 and 2 pressures
- Tank 1 and 2 temperatures
- Thruster inlet temperatures
- Thruster inlet pressures
- Pressurant Tank pressure
- Pressurant Tank temperatures

Upon FOT/POD approval of the Maneuver Command file, the FOT will transmit a Maneuver Approval file back to the FDF (the MOC will essentially echo the transmitted file back to FDF within 4 hours). After the approval process has been completed, a Delta-V maneuver command load will be generated.

Delta-V maneuver command loads will be generated and uplinked to the ACS ATS buffer (nominally buffer A, and buffer B will not be utilized). A Delta-V command load will be generated upon FOT/POD approval, and will typically be uplinked to the ACS ATS five to six hours prior to the Maneuver execution.

Due to the criticality in the timing of maneuver commands, the Delta-V maneuver will involve a cross communication between the ACS and S/C SCPs. Only the ACS processor load commands will be incorporated into the actual load, as the S/C Processor RTS commands will already reside on-board. During the loading of the ACS ATS, the FOT will ensure that the S/C RTSs required to perform the Delta-V are ENABLED.

All nominal Delta-V maneuver pairs will occur around 1:00 PM local time, for the first maneuver of the pair to allow for post-maneuver monitoring, planning of the next maneuver, and contingency response (if necessary) by the FOT, FDF, and Code 700 engineers. In addition, other observatory activities can easily be scheduled around Delta-Vs, if the Delta-Vs always execute at the same time of day. There are no requirements to provide real-time coverage of Delta-V maneuvers. CERES is the only instrument requiring reconfiguration prior to Delta-Vs. To avoid contamination, the CERES instrument will be placed into the Contamination Safe Mode. Figure 7.1-3 provides a graphical illustration of an actual Delta-V maneuver command load. A detailed description of the Delta-V maneuver (spacecraft operations) is provided in section 4.2.

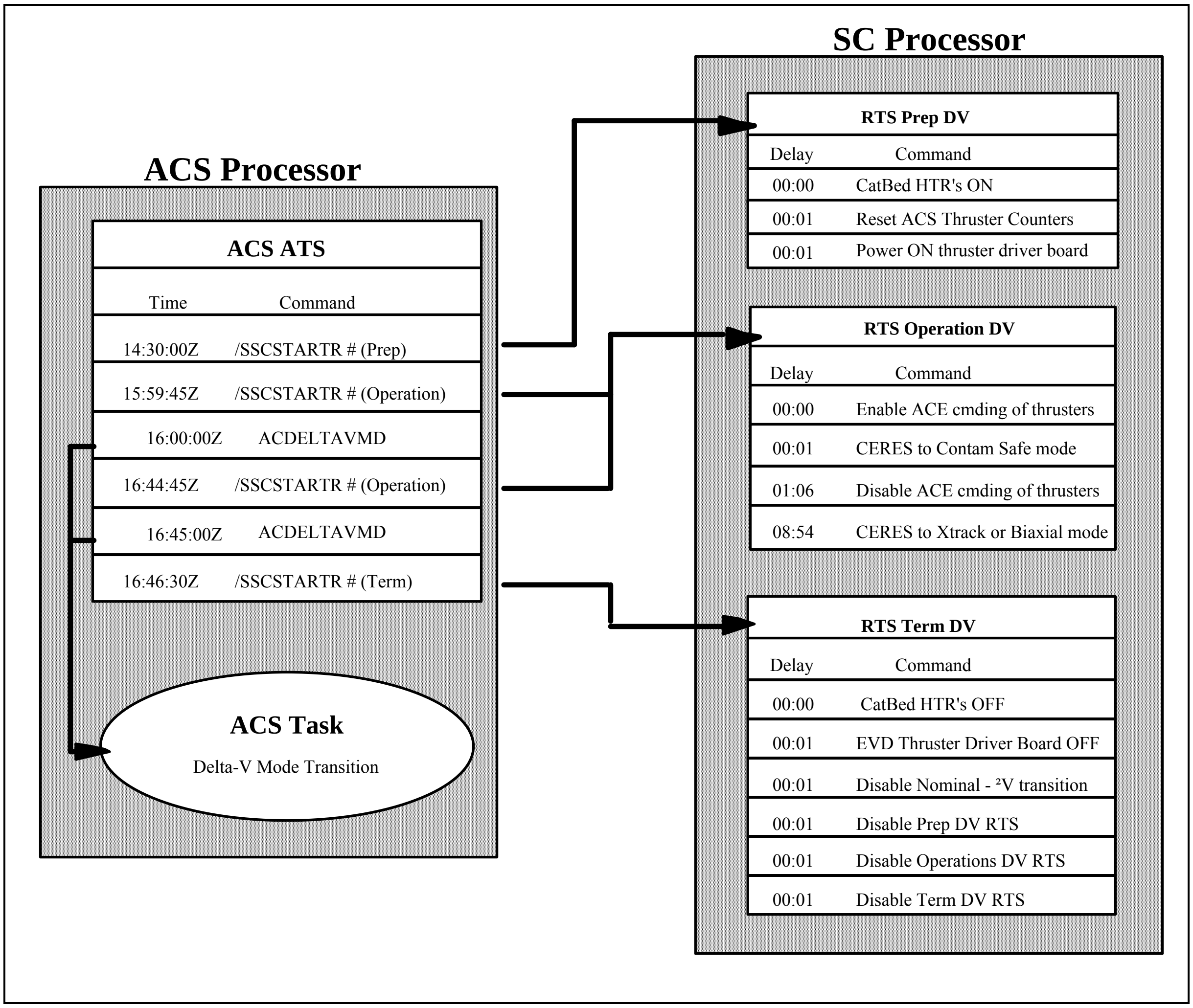


Figure 7.1-3 Delta-V Command Load

7.1.1.5 Yaw Maneuver Planning

Periodically (every 2 to 4 weeks), the TRMM spacecraft will require a 180° yaw maneuver to maintain a cold side of the spacecraft, as the Sun crosses the orbit plane (Beta 0° ± 1°). Operationally, the FOT will attempt to schedule the maneuver when the Beta angle reaches ±1° (prior to crossing 0°). This approach will provide approximately a 12 to 16-hour window in which to perform the maneuver. The FOT will receive daily and monthly Beta angle predicts from the FDF, and will determine when yaw maneuvers are required. When the yaw maneuver is required, the FOT will include the command (/ACYAWMANMD) and the proper S/C orientation (+X or -X) into the daily S/C load.

The Yaw maneuver will be planned such that the entire maneuver is performed in darkness. The maneuver will be performed in darkness to avoid the Sun shining into the VIRS cooler, and to avoid the possibility of CERES scanning the Sun. Yaw maneuvers will require approximately 16 minutes to complete (including settling time).

Like Delta-Vs, there is no requirement to provide real-time coverage of Yaw maneuvers. The first few however will definitely be scheduled with real-time coverage until the ACS engineers have developed confidence in the system. For the subsequent maneuvers, the FOT will attempt to schedule real-time coverage, if possible. Additionally, CERES is the only instrument requiring reconfiguration prior to Yaw maneuvers. To avoid the possibility of CERES scanning the Sun, the instrument will be placed in the Contamination Safe mode.

7.1.2 Outputs From Mission Planning

The outputs from the mission planning process are used by the FOT for performance monitoring, pass planning, contingency recovery, and as inputs to the load generation process. The specific outputs of the mission planning process include the DAP and the Mission Planning Timeline. The DAP is used during the Load generation process, and can be edited to incorporate changes. The Mission Planning Timeline is used to coordinate the scheduling of the instrument and spacecraft activities, and for notification to the remote instrument facilities.

7.1.2.1 Daily Activity Plan

The DAP serves as the basis for inputs to the load generation process. The FOT will nominally develop a single DAP from the activities on the Mission Planning Timeline. The DAP will include all commands required for routine spacecraft activities (i.e., real-time TDRS events) as well as commands for instrument activities, special command requests, and spacecraft maneuvers. The DAP will be edited to include the appropriate commands for each requested activity (i.e., instrument calibrations, yaw maneuver commands, etc...).

7.1.2.2 Mission Planning Timeline

A Mission Planning Timeline will be provided to allow a graphical illustration of scheduled activities. The Timeline is a menu driven, workstation based system that provides scrolling windows to allow viewing of selected activities and events. The Timeline will be used to display scheduled TDRS events, orbital events (Sunrise, Sunset, SAA, etc...), spacecraft maneuvers (orbit and attitude), and select command activities (CERES Shorts scan transitions, instrument calibrations, etc...). A report capability will also exist to provide schedule information to the instrument support facilities. As activities are scheduled, the Timeline will be updated and a report will be generated and distributed to the remote facilities (FDF, TSDIS, LaRC, MSFC, and EOC via TSDIS).

7.2 LOAD GENERATION

The purpose of load generation is to format inputs from the mission planning process into loads for uplink, and to manage designated areas of spacecraft memory. Sources for loads include the following:

a. DAP (ATSs and RTSs)
b. FDF, alignment and calibration tables.
c. OST, all other tables and memory areas.
d. Instrument microprocessor memory loads

The MOC's load generation process prepares loads for all processors and their designated memory. This includes primary and redundant S/C and ACS processor RAM and EEPROM, ACE-A, ACE-B, PSIB, CERES and VIRS instrument microprocessors. Inputs can be processed either as tables or as memory. For most operations, tables are used for the added level of safety that table loading provides. Inputs for the instrument loads are provided in a known format by the SOCC or LaRC, with MOC processing limited to checksum and APID validation, and memory command load generation.

After accepting and validating inputs, the MOC formats load data into either load_memory or load_table commands. Section 4.1 provides a more detailed description and illustration of system and stored command table/memory loads.

7.2.1 Inputs to Load Generation

Prior to load generation, a DAP (merged DAP) will be generated and preprocessed. After accepting and validating inputs contained in the DAP, the load generation process will begin. During the load generation process, the MOC formats load data into load_table commands.

7.2.1.1 Daily Activity Plans

A DAP is an ASCII file that allows the FOT to specify commands and directives in a high-level syntax. Every DAP contains a required header listing the source (FOT) and the planned start and stop times. DAP contents can include any combination of the following:

a. commands
b. macro invocations
c. RTS load directives
d. RTS start/stop/enable/disable directives
e. RTS expire directives (for MOC-managed RTSs)
f. text for reports

Figure 7.2-1 provides an example DAP.

Each entry in a DAP must have a time reference. In addition to UTC, the MOC supports timing relative to orbital events, spacecraft attitude-dependent events, and TDRS contacts. Modifiers, such as plus or minus x minutes, are used to further define execution times. The MOC System User's Guide contains a complete list of available events and modifiers. Load directives must have time "windows" associated with them rather than exact UTC times. This allows real-time operations personnel several command opportunities to accomplish the requested activities.

7.2.1.2 History Data

History data provides continuity from one planning period to the next. Several types of history data are required to ensure error-free operations. These include ATS buffer contents, RTS table contents, and spacecraft attitude. MOC software ensures that constraints are not violated in the transition from the end of one day to the beginning of the next. In addition, any commands from a plan that extends past the end of a day are retained in continuity files and are merged with commands for the next day. Typically, this results from a macro invocation near the end of the day.

```
HEADER  SOURCE=FOT, TYPE=daily,
START=1997:259:00:00:00, STOP=1997:259:23:59:59;
    RTSCTRL=START RTS_ TDW AOS_entry AT EVERY TDW MINUS 05:00;
    RTSCTRL=START RTS_ TDW LOS_entry AT EVERY TDW PLUS 00:30;
    RTSCTRL=START RTS_ TDE_entry AT EVERY TDE MINUS 05:00;
    RTSCTRL=START RTS_ TDE LOS_entry AT EVERY TDE PLUS 00:30;
    RTSCTRL=START RTS_AT EVERY SR AND SS EVENT MINUS 00:10;
    MACRO CERES SOLAR Cal AT 12:00:00
    ACYAWMANMD, +X AT 16:30:23
END_PLAN;
```

Figure 7.2-1 Daily Activity Plan Example

7.2.1.3 Definition Files

There are two types of definitions supported by the MOC, RTSs and macros. The FOT must ensure that the appropriate definitions exist in the MOC before attempting to call them in DAPs. RTSs and macros are submitted individually and are validated by the MOC. The RTS and macro definition files reside in FOT-assigned directories which will rarely, if ever, change.

As described in Section 4.1, RTSs are sequences of commands with time-tags representing a delay between each command (delay relative to previous command). RTSs are typically used for frequently executed activities, such as TDRS AOS and LOS commands, Delta-V maneuver preparation, and for actions associated with autonomous spacecraft Safing.

Conceptually, macros are sequences of commands with associated relative delay times. Macros are only used in ground processing, as inputs to command loads. MOC software calculates a UTC time-tag for each item in the macro for inclusion in ATS loads and reports. To the spacecraft, ATS commands arising from macros are not distinguishable from ordinary commands specified in DAPs. Two other major distinctions between RTSs and macros are:

a. macros may contain text (for inclusion in reports)
b. macros may contain parameters (for commands, submnemonics, and delta times)

Macros are also convenient for activities that are not performed frequently enough to warrant RTS space or for activities that are too long or complex for re-typing each time they are included in a DAP. By changing a macro's execute time in the DAP, all of the commands can easily be adjusted. CERES instrument solar calibrations are well-suited for definition as a macro, with the appropriate azimuth angle included as a parameter. Figure 7.2-2 provides an example of a macro definition.

```
HEADER  SOURCE=FOT, TYPE=DEFPLN;
DEFINE CERES SOLAR CAL_entry, TYPE=MACRO;
        /CAZPOS, SOLCAL=22.2, DELTA=00:00;
        /CINSTMODE, CSTBY, DELTA=00:01;
        /CINSTMODE, SOLCAL, DELTA=00:02;
        /CINSTMODE, XTRK, DELTA=00:03;
END_DEFINE;
END_PLAN;
```

Figure 7.2-2 Macro Definition

7.2.2 Pre-processing

Pre-processing ensures that all required DAP elements are present and are syntactically correct. Pre-processing only involves ATS and RTS loads, and will not be performed for table/memory or instrument microprocessor loads. The following actions will take place:

a. Event relative times are converted to absolute times
b. Statements are ordered
c. Macros and RTSs are expanded
d. RTS control commands are generated
e. Uplink requests are validated
f. RTS table usage is determined
g. RTS history file updates are generated
h. ATS and RTS binary command files are built

At the conclusion of pre-processing, the MOC generates reports listing processing status and explanations of any error conditions. Upon successful pre-processing of the input files, the load generation process will autonomously begin.

7.2.3 Load Processing

For all loads, the MOC "encases" the data into load commands and computes the CCSDS secondary header checksum for each. For table/memory loads, the MOC also supplies other load command parameters such as the offset and number of words. For all tables, the MOC adds a "select" command with the correct parameters, which includes the table identifier, from_image (RAM or EEPROM), and commit operation. The default for commit operation will be "commit with word count" but the FOT will be able to override this, allowing commit without verification. The following paragraphs provide a detailed description of the MOC load processing provided for each type of load.

7.2.3.1 Spacecraft ATS Loads

For spacecraft ATS loads, the MOC uses history data to determine which buffer the "select" command should identify. At the end of each load, the MOC appends a "switch_buffer" command that stops the current buffer and starts the next. The FOT can set the criteria for the switch command's time-tag. Normally, it will be scheduled to execute at 23:59:59z (end of each day). The MOC constraint checks the load to ensure that the first command in the load is, at a minimum, one second later than the last command in the previous load (usually the switch command). Should this constraint be violated, the FOT can take one of several options depending on the circumstances. These options include adjusting the time of the first command, patching the previous load, or even commanding the switch in real-time. This minimum load separation delta time can be respecified in the spacecraft characteristics file.

The structure of an ATS load is similar to the general structure for table loads. The differences are the select command, which can take "append" as a parameter, and a switch_buffer command at the end. The switch_buffer command tells the Stored Command task when it should stop processing the current buffer and switch to the other buffer. Figure 7.2-3 illustrates the ATS load format.

select_storedcommand_table, table_id=xx, from_image=xx, commit_operation=xx
load_table, offset=xx, num_words=xx, load_data=[ATS command ATS com-]
load_table, offset=xx, num_words=xx, load_data=[mand ATS command ATS comma-]
load_table, offset=xx, num_words=xx, load_data=[nd ATS command ATS command-]
load_table, offset=xx, num_words=xx, load_data=[ATS command <switch_buffer>]
commit_table, word count=xx

Figure 7.2-3 ATS Load Format

7.2.3.2 ACS ATS Loads

For ACS ATS loads, the MOC will always use Buffer A. The MOC constraint checks the load to ensure that no load already exists on board the spacecraft for the specified time period. Should this constraint be violated, the MOC will provide a message to advise the FOT of the potential conflict. Since the ACS ATS Buffer is only used to perform two activities (Delta-V maneuvers and EPV loads), this constraint should not be violated. For TRMM, an EPV load will be generated and uplinked daily. In addition, a Delta-V command load will also be generated, as frequently as every other day (as solar activity intensifies). Since the Delta-V commands also include an EPV command, separate EPV loads will not be generated and uplinked when Delta-Vs are performed. Based on the constraint violation, the FOT will determine the proper response to the conflict (i.e., If generating a Delta-V and an EPV exists, the load will overwrite the existing buffer contents. If generating an EPV load and a Delta-V load exists, the EPV load will not be uplinked.). In support of Delta-V and ACS operations, the TRMM FDS possesses the capability to start an RTS on the S/C processor from the ACS processor. Operationally, the ACS

ATS will be operated in a single-operation, start-stop mode. That is, each activity will be loaded into memory, the ATS started, the activity run, and at its conclusion the ATS will terminate.

7.2.3.3 RTS Loads

RTSs for the S/C and ACS processors are distinguished by APID, which the MOC software supplies based upon the load generation keyword from the DAP. Constraint checking and knowledge of on-board activities rely upon an accurate record of which RTSs are in each processor. MOC software tracks the contents of all RTS tables for this purpose.

For MOC Managed RTS tables, the MOC supplies "start_RTS" commands to handle chaining RTS tables together to accommodate RTSs larger than a RTS table (currently RTS tables are 300 bytes). RTS loads are similar to ATS loads in that the select command is select_storedcommand_table and the command entries are packed in load_table commands. The MOC also places an Enable command in each RTS load file so that the RTS can be enabled immediately after the RTS is successfully committed. The FOT can choose not to send this command if it is preferable to leave the RTS disabled. Situations which would warrant this include RTSs used for testing, special purpose RTSs, or a long chain of RTSs. In these situations, the Enable commands would be transmitted when the RTSs are required for execution, or after the last RTS in the chain is successfully committed. Figure 7.2-4 illustrates the RTS command load format.

select_storedcommand_table, table_id=xx, from_image=xx, commit_operation=xx
load_table, offset=0, num_words=xx, load_data=RTS command1 RTS com-
load_table, offset=xx, num_words=xx, load_data=mand2 RTS command3 RTS-
load_table, offset=xx, num_words=xx, load_data=command4 RTS command5
commit_table, word count=xx
enable_RTS, table_id=xx

Figure 7.2-4 RTS Load File Format

7.2.4 Table/Memory Load Processing

For table/memory loads, the MOC will process table or memory image data as received from the OST, either autonomously or by FOT requests. The MOC will verify the Flight Software table size (using table definition files), and generate a table/memory load. The following paragraphs describe the table and memory load processing required for TRMM.

7.2.4.1 Table Loads

For table loads the MOC will supply load command parameters such as the offset and number of words. For all tables, the MOC also adds a "select" command with the table identifier, from_image (RAM or EEPROM), and commit operation (the default for commit operation will be "commit with word count"), which will be included at the end of the load. Figure 7.2-5 illustrates the conceptual layout of a table load.

select_system_table, table_id=xx, from_image=xx, commit_operation=xx
load_table, offset=xx, num_words=xx, load_data=xxxxxxxxxxxxxxxxxxxxxxx
load_table, offset=yy, num_words=xx, load_data=xxxxxxxxxxxxxxxxxxxxxxx
load_table, offset=zz, num_words=xx, load_data=xxxxxxxxxxxxxxxxxxxxxxx
commit_table, word count=xx

Figure 7.2-5 Table Load Format

The default select_system_table values for full table loads are: from_image=null and commit=replace active. During the uplink process, the MOC software allows the select command to be respecified. This allows specific parameters to be modified (i.e., a load originally built for RAM can be modified to be loaded to EEPROM, and vice versa). This is useful for contingencies, such as reloading after a cold reset, and for modifying EEPROM after verifying new loads in RAM.

For partial table loads, the target table is copied into the working buffer, either from EEPROM (if from_image is initial) or from RAM (if from_image is active). The offset in the load_table command instructs the FDS as to where the partial load begins.

7.2.4.1.1 Table Commit Operations

The nominal means for verifying that table loading was successful is an automatic load length comparison. Upon word count match, the table in the working buffer is copied to RAM or EEPROM, depending on the commit parameter in the select_table command. For full, partial, or patch loads, MOC software includes the auto commit, with the computed word count, as the last command in the load file. Loads can be committed without verification, but operations procedures require that they be dumped and compared against either the GRI or the load file for assurance that the load operation was successful. Note that the uplink protocol and the secondary header in each command packet provide a degree of assurance that the load commands have reached the spacecraft intact. For certain tables, both types of commit (with and without word count) are only acted upon after handshaking with other FDS tasks. This prevents tables from being altered while the "owner" FDS task is reading data from the table. Tables subject to this handshaking are defined in the FDS's table of tables as "non-jam loadable".

Telemetry verification that the commit command was successful triggers MOC software to update the contents of the GRI with the contents of the load. GRIs are used to keep track of memory contents of various TRMM processors. A more detailed description of the GRIs and the image maintenance process is provided in Section 6.5.

7.2.4.2 Memory Loads

A memory load consists of a series of load_memory commands, each containing the destination memory type, number of data words, the start address, and the load data. Destination memory type is either RAM or EEPROM, as these are the only loadable memory areas on orbit. The number of data words is applicable only to the data in the individual load_memory command, and no cumulative counters are kept on board for an entire load. Figure 7.2-6 illustrates the contents of a typical memory load.

load_memory, mem_type=xx, address=aaaa, num_wds=xx, load_data=xxxxxxxx
load_memory, mem_type=xx, address=bbbb, num_wds=xx, load_data=xxxxxxxx
load_memory, mem_type=xx, address=cccc, num_wds=xx, load_data=xxxxxxxx
load_memory, mem_type=xx, address=dddd, num_wds=xx, load_data=xxxxxxxx

Figure 7.2-6 Memory Load Format

7.2.5 Memory Management

One of the most critical functions of the load generation process is memory management. The following memory areas are managed by the MOC:

a. ATS buffers
b. MOC-managed RTS tables
c. Reserved RTSs
d. Tables

Limited memory management consists of verifying loads will fit into the designated load destination. The user can chain sequences if necessary. For MOC-managed RTSs, the MOC will assign memory areas as necessary.

7.2.5.1 ATS Buffers

The Stored Command task manages two ATS buffers capable of holding 600 commands or 10,000 bytes, which is appropriate for 24 hours of operations. The MOC builds ATS loads and incorporates the proper buffer selection in the select_storedcommand_table at the beginning of each load. By alternating buffers, a new load can be uplinked several hours before it is needed, thus eliminating requirements for overlapping loads. The FOT will load Buffer A, while daily operations are conducted via Buffer B (and vice versa). This sequence will repeat daily. Figure 7.2-7 illustrates how the ATS buffers will be alternated to accommodate daily operations.

For ATS loads that are too large, the MOC will split the load into two parts. Certain rules govern this splitting capability to ensure that constraints are not violated and that an adequate load window is provided while the second (usually smaller) load is executing. The MOC will split loads such that at least a one second gap exists between the "switch" command, at the end of the first load, and the first command in the second load. The MOC will also split loads such that each load segment spans a minimum of three hours. This value is DataBase defined and can be changed should the FOT find that longer or shorter load windows are required. However, at this time the FOT does not currently plan to use this capability.

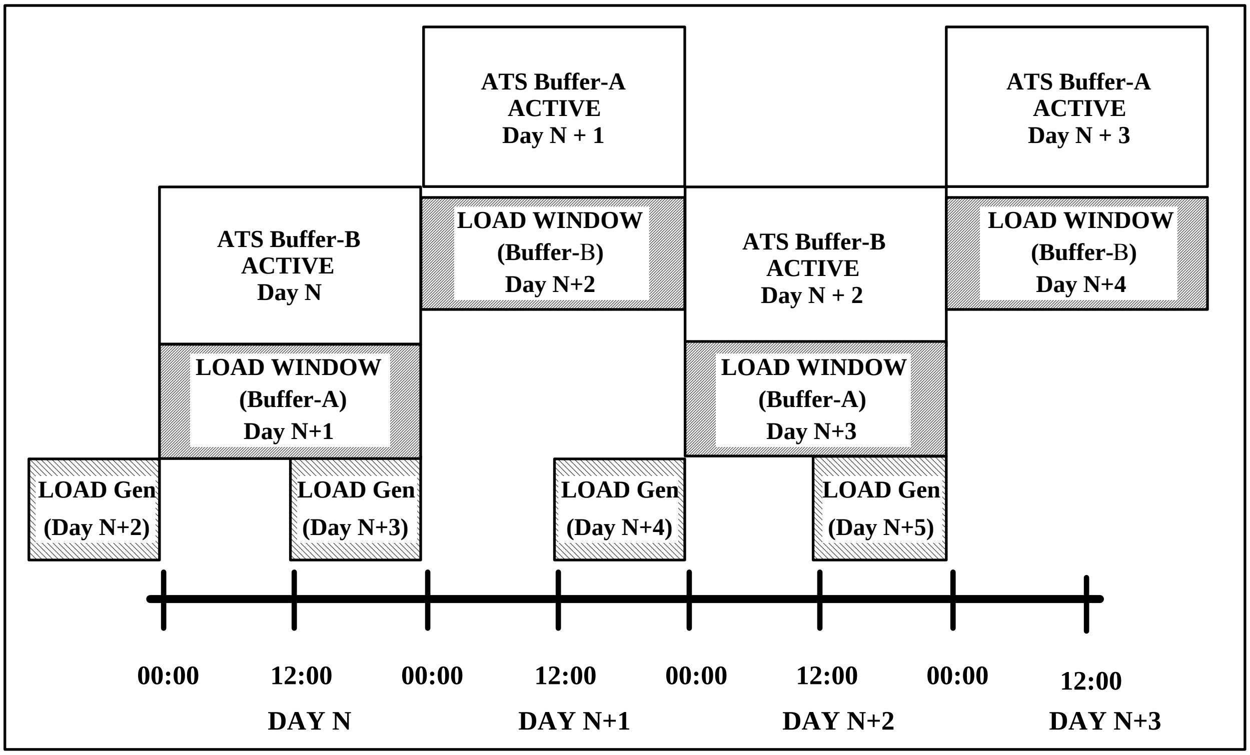


Figure 7.2-7 ATS Buffer Switching

At the option of the FOT, space may be reserved at the end of each buffer to ensure that adequate space is available for patching, as shown in the Figure 7.2-8.

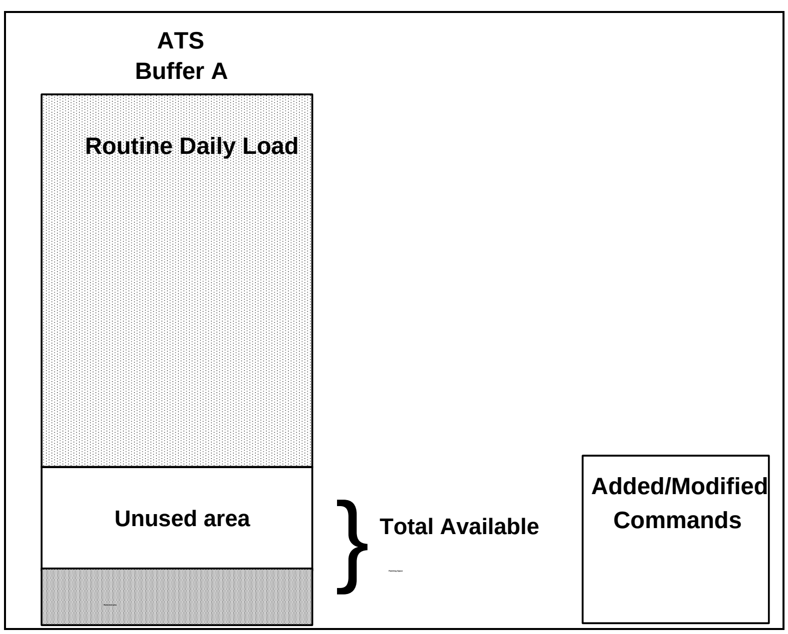


Figure 7.2-8 ATS Buffer Management

The amount of available space will be the DataBase-defined reserved amount plus any additional unused space. That is, on days with short loads, more space is available. The MOC maintains maps of ATS memory so that the amount of available space in each buffer is known at all times. This is critical for building loads for the correct buffer and for ensuring that patches will fit in the available space.

7.2.5.2 RTS Management

MOC software supports two types of RTS management, reserved and MOC-managed. RTS tables are assigned to these categories based upon their intended usage. MOC-managed RTSs, which will include instrument RTSs, relieve the TSDIS SOCC from maintaining and managing RTS memory space. Based on user-supplied load expire times and a DataBase list of MOC-managed tables, the software can determine which RTSs are available for new loads. For reserved RTSs, the user must specify a valid reserved RTS number with the load request in the DAP. Some reserved RTSs will be designated as "restricted" in the MOC DataBase. RTSs loaded into a reserved slot stay there until overwritten by another RTSLOAD statement requesting that same slot. Explicit actions defined in operations procedures are required to allow restricted RTS updates. This is designed to prevent accidental reloading of RTSs used by flight software. RTSs called by flight software, such as Telemetry/Statistics Monitor Safing RTSs, are designated as restricted.

7.2.6 Load Generation Outputs

The MOC will provide a Load Generation Status display to consolidate all information required during the load generation process. In addition to the Load Generation Status display, various reports will also be provided (Integrated Print, ATS Memory Map, RTS Memory Map, etc...). These reports will be generated and made available to the FOT and remote instrument facilities as required.

The Load Generation Status Display will provide a graphical depiction of the load generation status. The load generation status display will include the Confirmed TDRS Schedule, TDRS ODB, FDF supplied PSATs and UAVs, Orbital Events ODB, DAP, S/C SCP Binary Command File (BCF), S/C ATS Load, and Approved and Uplinked Status for a user specified duration (typically a one week period). Using this display, the FOT will be able to determine the status of the load generation process for a given day. The FOT will also be able to determine if all inputs required for the load generation process exist in the MOC.

7.2.7 Command Load Modifications

The FOT will use various methods to modify command loads. If the loads have not been generated, or have been generated but not uplinked, the FOT will simply edit the DAP and regenerate the load. However, if the load has already been generated and uplinked to the spacecraft, the FOT will either generate a patch plan or regenerate the entire load and uplink to the other ATS buffer (depending upon the severity of the change and the amount of time remaining until the changed commands are scheduled to execute). The following paragraphs provide a detailed description of command load modifications to be performed by the FOT.

7.2.7.1 Patch Plans

Patch plans are used to make minor alterations to an ATS load already loaded into the spacecraft. The flight software only allows changes to an ATS load via the append function, which is described in Section 4.1. The MOC reads the submitted patch plan and performs cursory checks on the contents. These checks ensure that the commands in the plan are valid. Prior to submitting the patch to load generation, its size is checked to ensure that it will fit in the available buffer space. History data from the previous planning period contains information about available space in the ATS buffers. When patching the ATS processor, new commands do not eliminate old commands which are being replaced. Instead, ATS pointers are removed from the old commands to prevent execution, and new pointers are placed at the commands in the patch. Figure 7.2-9 illustrates an example of a patch plan.

```
HEADER  SOURCE=FOT, TYPE=PATCH, LOADNAME=TRMM256.ATS,
        START=1997:256:00:00:00, STOP=1997:256:23:59:59;
ADD;
        /DSEVTDMP\VR=7, time=1997:256:14:45:00;
        /CMD2, time=1997:256:14:48:00;
END_ADD;
REPLACE CMDNO=202:203;
        RTSCTRL=START RTS_test, time=1997:256:14:50:00;
        /NOOP, time =1997:256:14:55:00;
END_REPLACE;
END_PLAN;
```

Figure 7.2-9 Patch Plan Example

7.2.7.2 Regenerated Loads to Other Buffer

In the event of a change to spacecraft or instrument activities requiring regeneration of an existing load already loaded onboard the spacecraft, the load can be regenerated for inclusion into the other ATS buffer. The FOT will make the required changes (to the DAP), and regenerate the load. During the load generation process, the FOT will specify that the load should go to the other buffer. After the load is generated and uplinked, the FOT will issue a real-time command to stop the current ATS buffer, and switch to the other buffer (buffer containing the regenerated load). Subsequent ATS loads will be autonomously generated for the correct buffer (from history data).

7.3 TDRSS SCHEDULING

Due to the limited on-board recorder storage capacity (approximately 215 minutes), the mission has a requirement for a real-time support every orbit, in order to playback the recorder. Failure to obtain a real-time support during any particular orbit may result in the loss of TRMM science data. The following sections will outline TRMM's contact requirements and the baseline scheduling methods.

7.3.1 TDRSS Scheduling Requirements

The baseline TDRS support requirements for the mission are one 20-minute real-time event each orbit. Due to the large number of Delta-V (Orbit Adjust) maneuvers and the potential for orbit uncertainty in the long-term predicts, the FOT will nominally mask 5-minutes (this number will be determined once on-orbit, to maximize the scheduling of TDRS resources) from the beginning and end of each view period. The FOT will submit each TDRS schedule request centered around the middle of the view period, as depicted in Figure 7.3-1. To allow additional flexibility in the scheduling of TDRS events, the FOT will also submit all schedule request with +/- tolerances. This will allow the NCC to schedule TRMM events anywhere in the TDRS view period, minus the FOT specified masks.

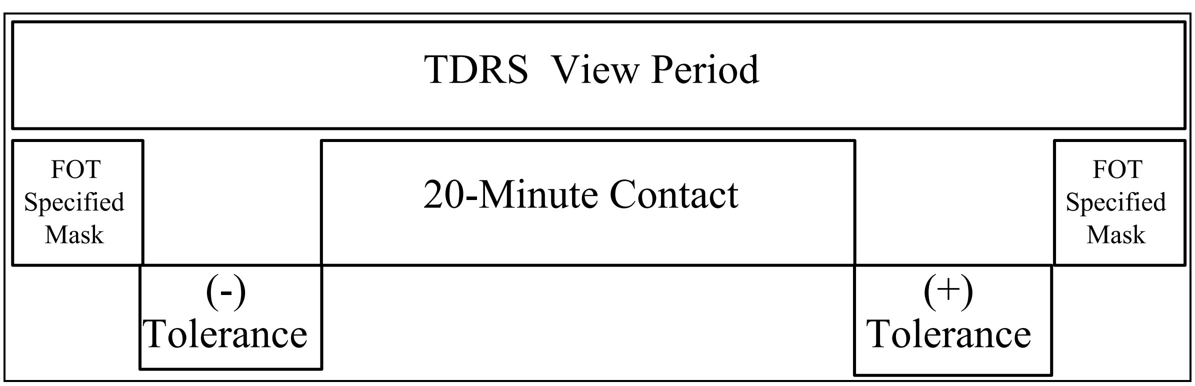


Figure 7.3-1 TDRSS Scheduling

The FOT will also attempt to schedule TDRS events such that an alternation between TDE and TDW occurs after 3 successive events on a particular TDRS (i.e., TDE, TDE, TDE, TDW, TDW, TDW, TDE,.....), and the switch will be scheduled such that a short turnaround between TDRS events will occur. The reason for this type of scheduling approach is twofold: better tracking data can be provided to FDF and the mitigation of the effects of a TDRS outage (or preemption by a higher priority user, such as the Space Shuttle). Potentially, we may have two supports during the same orbit when switching between TDRSs (this may occur 5-6 times per day).

Daily, during one of the short turnaround events, the FOT will schedule a switch to DG1 Mode 2 during the later portion of the event (approximately the last 10-minutes), to allow the FDF to obtain one-way tracking data in order to perform TCXO center frequency measurements (FOT will alternate between XP-1 and XP-2 every other day). The significance in the short turnaround event is the scheduled recorder playback should be short in length, which should allow ample opportunity for the switch to mode 2.

Figure 7.3-2 provides a graphical illustration of a typical TDRS schedule for a 12-hour period.

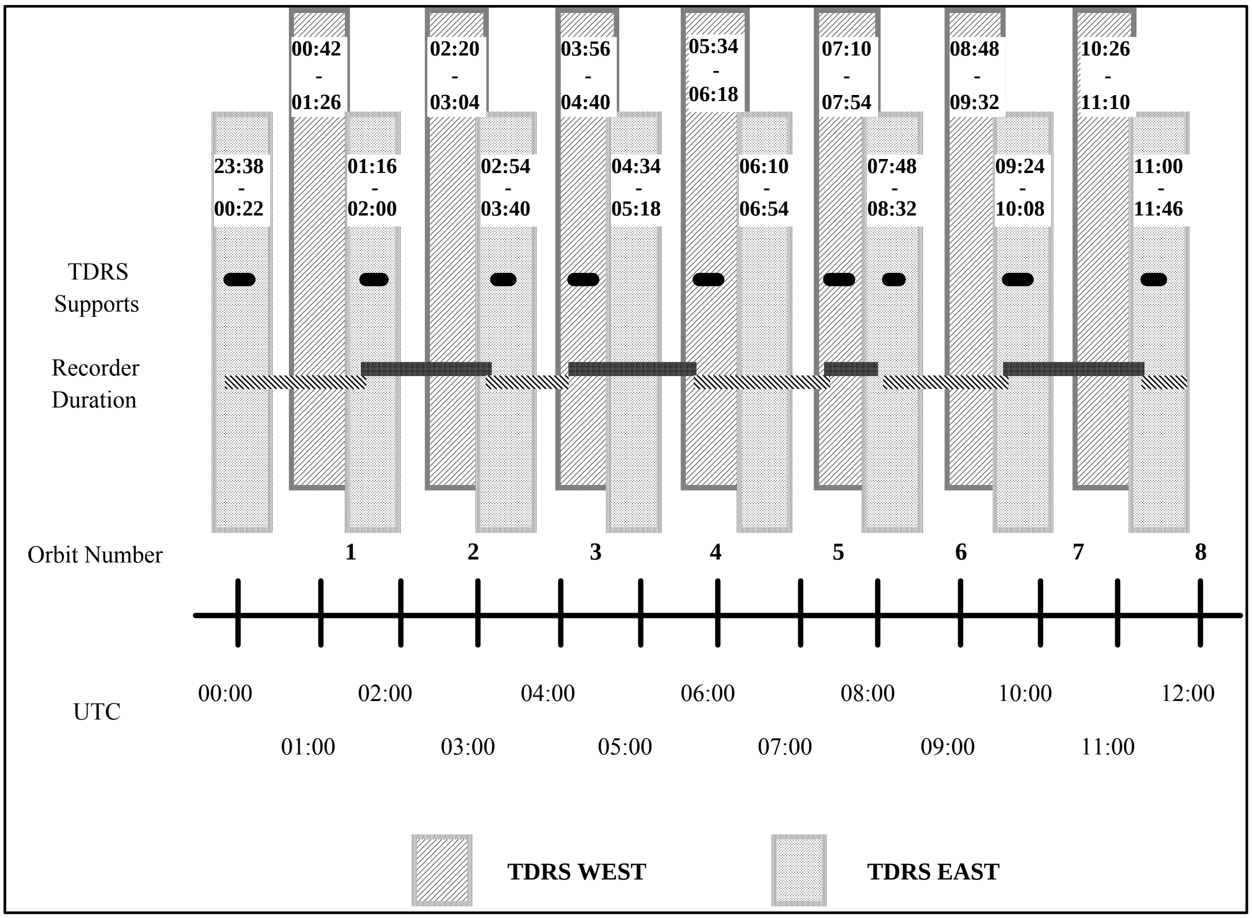


Figure 7.3-2 Typical 12-Hour TDRS Schedule

The above scheduling scenario will typically result in the scheduling of 18 -20 TDRS events per day.

7.3.2 Pre-launch Set-up

As with most missions, TRMM's configuration and scheduling criteria are established and refined during the Pre-Launch phase. Once all expected and viable operating modes are defined in the NCC and UPS databases, changes should rarely occur. One of the earliest steps during

Pre-Launch is the definition of configuration codes. These configuration codes specify the characteristics of the TDRSS services which the mission intends to use. Following configuration code definition, prototype events can be defined which specify a fixed combination of service configuration codes and their associated timing. The prototype event (PE) allows a more convenient method of describing contacts that always involve the same combination of services. The definition of PEs allows a much easier method of TDRS scheduling (since all detailed information is not required to be specified for each schedule requests). Table 7.3-1 provides an example of a prototype event used by TRMM.

Service	Offset From Event Start	Duration	Configuration Code
SSA forward	00:00	20:00	H01
SSA return	00:30	19:30	J01
2-way tracking	00:40	10:00	T01

Table 7.3-1 Sample Prototype Event

Like configuration codes, PEs are defined in the NCC and UPS databases. In addition, the UPS supports locally defined events that allow the user to specify the desired combination of configuration codes but without specifying fixed duration and offset times.

After these contact specifications have been developed, a scheduling criteria can be defined which indicate to the UPS how to assign specific times to the various types of events during the weekly scheduling process. The UPS uses a pattern-matching approach in resolving the specific times. Therefore, a description of the desired pattern must exist in the UPS DataBase. For TRMM's alternation between TDE and TDW scheduling approach for real-time coverage, both primary TDRSs (one each in the "east" and "west" locations) are used. Therefore, TRMM's schedule pattern is tied to TDRS views and includes instructions about when to switch between TDRSs. Additional rules specify details such as:

a. Required minimum duration for each service type.
b. Separation time between events (Max. & Min.).
c. Conflict resolution preferences (i.e., try other TDRS).

The UPS supports both graphical and text-based interfaces for many of its functions. Schedule request patterns can also be defined graphically. Given the nature of TRMM's alternating TDRS events, the pattern used for routine scheduling is based on a three orbit period.

Once the service configuration codes, events, patterns, and other parameters are defined in the UPS DataBase, nominal TDRSS scheduling using automated request generation is possible.

7.3.2.1 TRMM Configuration Codes

Configuration codes are the medium whereby the SN provides real-time telemetry, command, and tracking services to all users. These codes provide specific information on the telecommunications link including carrier frequency, data rates, and other interface requirements for any TDRSS support request. TRMM configuration codes allow TDRSS support during nominal, contingency, and special modes of operation (i.e., Launch). Appendix C contains a summarization of the TRMM Configuration Codes.

Configuration codes are generated by the FOT and provided to NCC scheduling personnel for incorporation into the NCC DataBase. Once established in the NCC DataBase, support activity for TRMM can be conducted. Changes to any code must be reflected in the NCC DataBase before they can become part of the daily operational scheduling scenario. Changes to any configuration code will be implemented by the NCC after receipt of a written request from the FOT. These changes must be coordinated with both the NCC and UPS DataBase administrators.

While our configuration codes contain much technical information, the following are those items which are of general interest.

a. Doppler compensation - enabled for all codes
b. NCC will select the particular SSA antenna for any support
c. Initial rates (command and telemetry) are those rates at the start of any TDRS support
d. HGA polarization - LHCP
e. SSA support at high Q-Channel rates will be without Q-Channel deinterleaving (PN on I-Channel only) and may only be in the coherent mode as required of Data Group 1 Mode 3.

The SN will configure its equipment strings to support the initial data rates of any TRMM code.

7.3.3 TDRSS Scheduling Methods

The TDRSS network is scheduled by submitting requests to the NCC scheduling facility. The FOT will generate requests and interface to the NCC via the UPS. The UPS supports multiple missions, allowing each to develop databases of service configurations and their associated scheduling criteria. The UPS is located and maintained by the Multi-Satellite Operations Control Center (MSOCC), located in Building 14 at GSFC. The FOT will have a remote log-in capability via a MOC provided Workstation. The Workstation will be connected to the TPOCC LAN, allowing the FOT to run UPS functions with an X-terminal interface. Figure 7.3-3 illustrates the conceptual layout of the MOC-UPS-NCC interface.

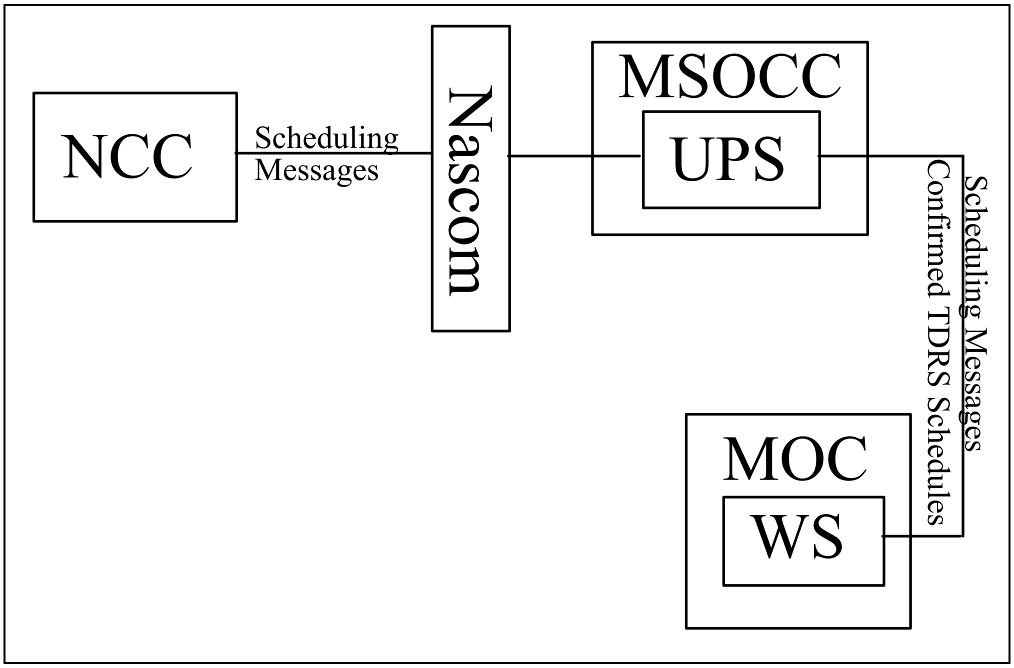


Figure 7.3-3 MOC-UPS-NCC Interface

After the NCC has accepted or rejected the requests, schedules are transmitted back to the FOT through the UPS. The remainder of this section describes the routine activities performed by the FOT to ensure TDRSS scheduling is successfully accomplished.

7.3.3.1 Weekly Scheduling Process

The scheduling process for TRMM begins three weeks prior to the event week. At this time orbital data from FDF will be sent to the MOC and are made available to the UPS. A session will be established on the UPS, from a MOC workstation, and the automatic request generation function will be initiated. For routine scheduling, all TRMM events will be scheduled following the previously defined scheduling guidelines. After reviewing processing summary reports and resolving any problems (insufficient supports, constraints violated, etc...) the requests will be sent electronically to the NCC.

During the following week, the NCC will perform conflict resolution for all users based on a priority criteria and TDRS availability. The NCC will contact the FOT in an attempt to resolve any conflicts. An attempt to resolve conflicts will be accomplished using a variety of methods, such as sliding a contact to an earlier or later time, or accepting a support of less than 20-minutes in duration. However, due to the nature of the TRMM recorders, supports of less than 14-minutes in duration will probably not be attempted during routine operations (unless nothing else is available). The user can attempt conflict resolution with the UPS graphical displays, which depict "problem" contacts in red. Depending on DataBase parameters for other missions, supports for other MSOCC UPS users may also appear on the display, easing the conflict resolution process. After making any necessary adjustments, the FOT reiterates the automatic request generation function, to incorporate decisions made during the process of conflict resolution. After reviewing the appropriate reports, the adjusted requests are electronically sent to the NCC.

By the end of the week, the NCC sends User Scheduling Messages (USMs) for all supports to the UPS. On the UPS, the USMs are merged into a single schedule for the week and are relayed to the MOC. This confirmed schedule will be forwarded to the FDF, LaRC, MSFC, and SOCC via a MOPSS timeline report. This schedule serves as the basis for the following mission activities:

a. Instrument activity scheduling
b. Maneuver planning and scheduling
c. Pass planning

Figure 7.3-4 provides a graphical timeline of the weekly TDRS scheduling process.

7.3.3.2 TDRS Schedule Changes

Schedule changes can occur anytime between event confirmation receipt and event start. Schedule changes can be initiated by either the FOT or the NCC. For both situations, the processing steps are essentially the same. The significant difference is that for FOT-requested changes, the appropriate schedule modification requests must be coordinated and then submitted via the UPS. For many NCC changes, such as pass deletion, the NCC will notify the FOT (usually a phone call) and transmit the USM containing the deleted pass. In addition, the MOC will provide an event message (via the Graphical Active Schedule Display), to ensure the FOT promptly receives the event deletion notification. If for NCC requested changes, an acceptable alternate time (or alternate TDRS) is available, the FOT must submit the appropriate requests and then wait for the USMs reflecting the changes.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT & SUN
Receipt of Weekly Planning Products (22-49) 22	23	24	25	Submit TDRS Schedule Requests (43-49) 26	27/28
Receipt of Weekly Planning Products (29-56) 29	30	Conflict Resolution, If Necessary (43-49) 31	32	33	34/35
Receipt of Weekly Planning Products (36-63) Comfirmed TDRS Schedule (43-49) 36	37	Conflict Resolution, If Necessary (50-56) 38	39	Submit TDRS Schedule Requests (57-63) 40	41/42
Receipt of Weekly Planning Products (43-70) Event Week (43-49) Comfirmed TDRS Schedule (50-56) 43	44	Conflict Resolution, If Necessary (57-63) 45	46	Submit TDRS Schedule Requests (64-70) 47	48/49

Figure 7.3-4 Weekly TDRS Scheduling

Most changes will occur in the "hours before" to the "days before" time frame and almost all changes will require immediate FOT action. Changes that occur late in the time frame may also require changes to the daily load.

If significant schedule changes occur far enough in advance, the FOT will request a new schedule from the NCC and perform the mission planning and load generation process again. This will ensure an accurate load to be generated and uplinked to the spacecraft.

7.4 PERFORMANCE AND TREND ANALYSIS

Performance and trend analysis are accomplished using the Generic Trending and Analysis System (GTAS), which resides in the MOC. GTAS supports multiple users concurrently, and operates in two modes, automatic (batch mode) and interactive. In the automatic mode, a set of telemetry mnemonics will be trended using standard tools, such as X-Y plots, X-Time plots, and Minimum, Maximum, and Mean (MMM) statistics. In the interactive mode, more in-depth analytical tools are available. The automatic mode will be used to identify or monitor trends in spacecraft status, while the interactive mode will primarily be used for anomaly investigation.

GTAS provides a broad range of functions, which include long and short term trending, statistical calculations, orbit signature analysis, report and plot generation, and data archival. Through a DataBase file of housekeeping telemetry, the FOT identifies specific parameters to be trended. GTAS provides the ability to trend up to 3000 telemetry points. GTAS can trend 24 hours of housekeeping data in 8 hours.

7.4.1 Set-up and Initialization

An initial set-up is required defining a subset of telemetry to be used in GTAS trending and anomaly investigations. This DataBase, referred to as the GTAS Master Index, includes telemetry mnemonics, as well as mnemonics output from MOC equation processors, special processors, and derived telemetry expressions. Up to 3000 mnemonics may be used by GTAS, however, the MOC only supports the capability to subset 2000 telemetry points at a time. Mnemonics may be subset in either the raw or engineering unit converted format. However, subsetting both formats uses two (of the 2000) available telemetry slots in GTAS.

GTAS initialization takes place at TPOCC boot up. The GTAS task waits for the creation of the telemetry subset file. Upon the receipt of the file, GTAS will automatically begin the daily trending. Daily trending includes but is not limited to statistical computations of the 2000 parameters and processing of FOT defined routines in parallel. GTAS can trend 24 hours of housekeeping data in 4 hours allowing completion in one eight hour shift. This trending session includes all calculations, data storage, and report/plot generation.

7.4.2 GTAS Input

There are three types of data input for the GTAS: Level Zero Processed data files, GTAS data files and TPOCC history tapes. Figure 7.4-1 illustrates the ingest GTAS data flow. Each type will be used for a different level of analysis. The 24 hour LZP data files will be used for daily trending. The TPOCC history tapes will be used to investigate suspected anomalies that can not wait for the LZP data files. And the GTAS data files will be used in the event that an anomaly occurs. This will require the FOT to search the GTAS DataBase for similar events in an effort to characterize the impact of the recent anomaly.

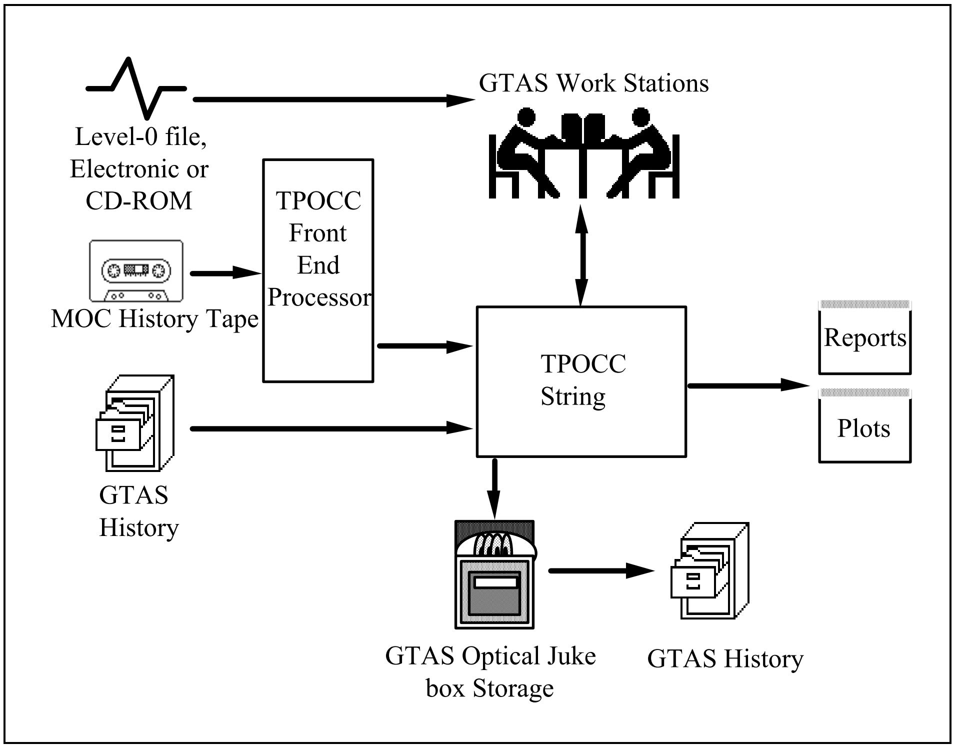


Figure 7.4-1 GTAS Data Flow (Components)

7.4.3 Long and Short Term Trending

Long term trending is performed on those parameters that do not change frequently or do not require quick action by the FOT. Long term trending is performed on the following subsystems: ACS, Power, Thermal, and Instruments. For example, gyroscope data will be trended long term.

Short term trending is performed on those parameters which change frequently or require quick action by the FOT. For example, spacecraft clock drift is a short term trending item because of the timing requirements of this mission. If a large drift occurs, the FOT responds by uplinking a new correlation factor. Short term trending is performed on other spacecraft parameters such as Transponder center frequency and spacecraft roll offset. Refer to the appropriate section for more detail on spacecraft performance requirements.

7.4.4 GTAS Processing

GTAS only processes data that has been subset through the MOC. The subset data contains mnemonic, data value in either raw or engineering unit form (or both), data quality flags, and limit information. Upon the receipt of the file, GTAS will automatically ingest and time sort the data, and then perform a Routine Analysis Request (RAR). The RAR defines plots and statistics to be generated daily, and is primarily used to identify or monitor trends in spacecraft health. Special FOT-defined analyses may be run as well, such as the power analysis program. The MOC provides a high-speed subsetting capability, used to process the large number of telemetry mnemonics and high data-rates on-board TRMM. The low-speed subsetting capability provides full MOC functionality during the subset process. High-speed subsetting will typically be used to process 24 hr LZP data from Pacor, while low-speed subsetting will be used for anomaly investigation.

The core capabilities of GTAS include Relational Telemetry Expressions (RTEs), Minimum, Maximum, and Mean (MMM) statistics' calculations, and X-Y or X-Time plots. These are described in the following paragraphs. Figure 7.4-2 describes the operational GTAS data flow.

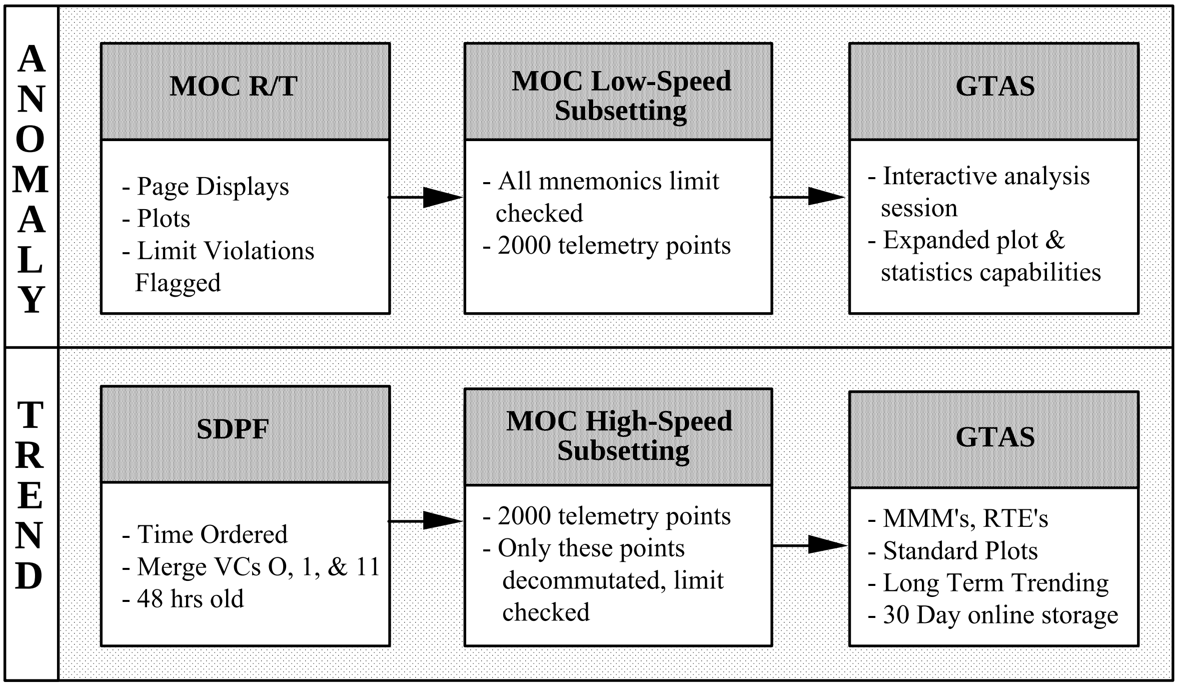


Figure 7.4-2 GTAS Data Flow (Data)

7.4.5 Relational Telemetry Expressions

Relational Telemetry Expressions (RTEs) output a list of mnemonics (and their values) to either a report or a plot. For example, ACS ephemeris X-, Y-, and Z-positions may be output for each occurrence where the battery depth of discharge is below a limit. RTEs will primarily be used to identify limit violations.

7.4.6 Statistics Calculations

GTAS supports minimum, maximum, and mean (MMM) statistical calculations as part of routine analysis. These computations are performed on a time basis or on an occurrence basis. Time based calculations have a resolution as small as milliseconds and as large as days. Occurrence based calculations have a resolution as frequent as every occurrence or as infrequently as necessary. Operationally, MMM calculations will be generated on hourly or daily intervals to identify or monitor long term trends in the spacecraft status.

7.4.7 FOT-Defined Routines

GTAS provides the ability to define mission unique routines through the application PV-Wave, a FORTRAN like programming language. The FOT will have the ability to develop routines and test them in the GTAS interactive mode. FOT-defined routines may also be run in parallel to the 24 hour trending operation. Such routines will include power analysis and predictive solar array power output.

7.4.8 Report and Plot Generation

Report and plot generation come in two types, interactively generated and automatically generated. Interactive plot generation is accomplished through the use of PV-Wave. In the automatic mode, the FOT will configure GTAS to generate pre-defined reports and plots through the RAR.

7.4.9 On-line Data Storage

GTAS data is stored in a Hewlet-Packard 40T Optical Jukebox. GTAS provides on-line storage for 2000 telemetry mnemonics for 30 days. MMM statistical data calculated over a one-day time period may be kept for the life of the mission. After 30 days the data will be removed from GTAS, however, additional optical disks may be used to retain data in the GTAS format. See section 7.6 for long-term archival of telemetry data.

7.4.10 Performance Trending Approach

During the pre-launch and continuing through the normal operations mission phases, the FOT will work with subsystem engineers to identify mnemonics required for trending. Plots and other reports required by engineers responsible for their subsystems will also be identified.

The FOT's nominal approach to performance trending is to receive a LZP data file from SDPF once per day. This data file contains 24 hours of spacecraft housekeeping telemetry. The MOC, upon receipt of a Level-0 file from the SDPF, will autonomously initiate a high speed subsetting process on the Level-0 processed file to produce a binary subset file for the GTAS. The GTAS software will be started shortly after the high speed subsetting operation begins, such that both tasks will be executing in parallel. Within 8 hours of receiving the data file, GTAS will provide the FOT with reports and plots for the 24 hour period. Additionally, once per day the FOT will subset a one-orbit time span of recorded data captured in the MOC and perform trending. This will identify trends of a more immediate nature.

In the event of an anomaly, the FOT will use the data captured in the MOC during recorder playback to perform analysis. MOC real-time tools may be employed (such as page displays, GenSAA, and sequential prints) as the low-speed subset operation occurs.

The FOT will work with subsystem engineers to identify the subset of telemetry points to be trended. Routine trending operations will occur during off hour shift, to free up resources during the prime shift when data analysis by day staff will occur, as well as most non-nominal spacecraft operations.

7.4.10.1 Delta-V Post-Maneuver Trending

Trending will be performed subsequent to every delta-V maneuver for verification of the maneuver and as inputs to FDF for the next maneuver. The following information is needed by the FDF:

- Maneuver start and stop time
- Tank temperatures
- Tank pressures
- Thrusters used
- ON time for each thruster

The maneuver start time and ON time for each thruster will be provided to the FDF as soon as possible following the maneuver. ON times for each thruster will be provided via the thruster table which will be dumped at the first pass after the maneuver. This data will be used by FDF to reconstruct and calibrate before planning the next orbit maintenance maneuver. The remaining data, which will be included in the post maneuver report, will be provided to FDF within 4 hours. Both pre-burn and post-burn information will be provided in this report.

7.5 PROJECT DATABASE

At the center of all TRMM ground data processing activity is an operational DataBase consisting of telemetry and command packet specifications, NCC message specifications, and definitions of system tables and flight status event messages associated with TRMM's on-board computers. The Project DataBase (PDB) refers to the collection of files which are transferred among ground facilities. An operational DataBase is compiled from the PDB.

The PDB may be edited and transferred among facilities. A runtime version used by software in operations is referred to as the Operations Data Base (ODB).

7.5.1 Command Records

Command specification records define the bit structure of command packets. For TRMM, there will be only one command packet per command frame. Additional DFCD fields in command records specify the following:

a. command criticality; Critical commands require extra operator direction to transmit them to the spacecraft. Critical conditionality may apply at both the command and submnemonic level.
b. valid real-time, ATS, or RTS command.
c. end-item telemetry verification of the commands' successful execution on board the spacecraft
d. special processing performed by the MOC. For example, MOC processing for CCSDS control commands.
e. Command Action Routines invoking functions for special processing of the bit structure of command submnemonics.

For TRMM various Command Action Routines have been defined. Table 7.5-1 details TRMM command action routines.

Name	Description
POLYNOMIAL	Converts input value by a calibration curve. Polynomial coefficients may be specified on a per-command basis.
TWOSFLIP	Converts value via two's complement and bit reverses.
XPONDERFREQ	Converts input value by Transponder algorithm. This action routine is used to specify Transponder center frequency.
COMMWRDCNT	Commit word count.

Table 7.5-1 Command Action Routines

7.5.2 Telemetry Records

Telemetry specification records define the bit structure of telemetry packets. Only housekeeping telemetry is defined in the PDB (no science data or instrument microprocessor dump packets). Additional fields support the following capabilities:

a. Invoke a SAVE function to retain the last valid telemetry value until the next pass.
b. Context dependent decommutation, under which the telemetry mnemonic will not be decommutated unless another telemetry mnemonic is within a specified range.
c. Engineering Unit (EU) conversion routines. Each EU converted mnemonic has a unique calibration curve specified to it.
d. Red/Yellow limit specifications.
e. Delta limit specifications, in which the absolute change in value between successive occurrences is to be checked.
f. Linear conversion defining joint pairs (x, y), where x represents the raw value and y represents the corresponding EU-converted value.
g. Polynomial conversion, in which the coefficients are defined for polynomial EU conversion. Up to a 7th order polynomial may be expressed.

Telemetry equation processing may be defined through DataBase records. Equation processors are predefined and hard coded in the software. Input and output parameters to these equation processors are invoked in the DataBase. Telemetry constants, such as PI (π), may also be defined and used as inputs to equation processing. Equation processing results are referred to as pseudo telemetry mnemonics.

Simple equation processing, referred to as derived telemetry, is also supported. A derived parameter is the result of performing a mathematical operation on a combination of existing telemetry parameters, derived parameters, and constants.

The creation of composite telemetry values are supported. A composite mnemonic takes various segments in a telemetry packet and concatenates them in the order of their occurrence in the packet. An example of a composite mnemonic takes the XP commanded state (Coherent or Non Coherent) and XP lock to derive the actual coherency of the transponder.

Spacecraft event messages originating from the FDS, ACS, and ACE are also defined in the PDB. FDS event messages contain ASCII text downlinked in telemetry. However, ACS and ACE event messages contain status codes which the PDB converts to text. For all event messages foreground and background colors may be defined.

7.5.3 Flight Software Table Records

Software tables residing on the S/C and ACS processors are defined in the PDB. Both static and dynamically changing tables may be defined. For each table individual entries are defined by table parameter mnemonic, Engineering Units of the mnemonic, and a mnemonic descriptor. Discrete state conversion of table values are also supported.

Table specification records are used to specify relative table location in memory for use in GRI processing. Further, formatted reports based on mnemonic definitions of spacecraft tables are supported.

7.5.4 NCC Message Definitions

NCC message records define messages received from the NCC in real-time and specify the parameters within the messages that are available for display. Both incoming User Performance Data (UPD) messages and transmitted Ground Control Message Requests (GCMRs) are defined.

7.5.5 PDB Distribution

Initial development of PDB command and telemetry specifications is accomplished by Code 700 integration and test personnel using the Record Definition Language (RDL) common to GSFC I&T systems. The TRMM PDB Data Format Control Document (DFCD) defines DataBase content and allowable record formats for PDB transfer to the Code 500 and external ground systems. To comply with the DFCD, the TRMM Software Systems Manager will provide conversion of the PDB from RDL to the DFCD format. The TRMM Software Systems Manager, who will augment the files with table definition records and perform configuration control management of distributed databases, will provide the PDB on 4 mm tape to the FOT. The DataBase is then installed in the MOC, and the FOT will add limit definitions, update critical command definitions, end item telemetry verifiers, as well as other DataBase fields. The FOT will then distribute the DataBase to other ground elements. After L&IOC operations have been completed, all PDB updates will originate from the FOT.

Prior to launch, MOC software releases and spacecraft tests with the ground system serve as the primary drivers for the PDB delivery schedule. However, additional interim PDB deliveries may be required on an as-needed basis. Figure 7.5-1 provides an overview of PDB distribution.

DataBase deliveries will occur a number of times as subsystem command and telemetry definitions become finalized in the Pre-launch test period. NCC Message Specifications will be delivered initially by MOC developers and are not expected to change during the life of the mission.

The FOT is responsible for adding information not received from I&T and required for on-orbit operations. The FOT will perform all editing required to mature the PDB to a suitable state. The following items detail specific information which is either not transferred from I&T (on tape) or is not suitable for orbital operations as received from I&T.

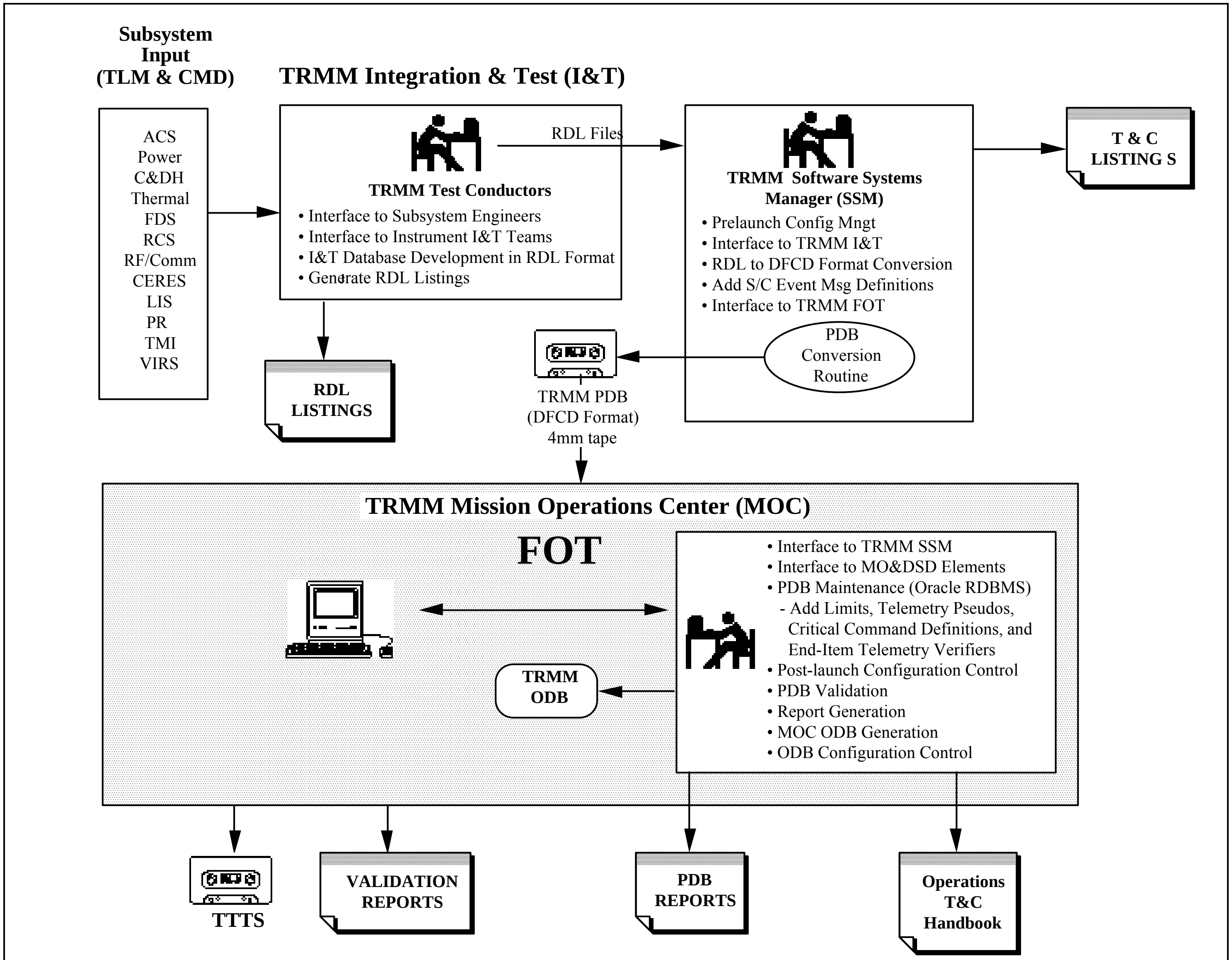
a. Telemetry Limits. Red Low (RL), Yellow Low (YL), Yellow High (YH), and Red High (RH) limits are transferred from I&T on tape. However, many of the limits are based on an ambient I&T temperature environment and must be updated for on-orbit use.

b. Pseudo Telemetry. These are telemetry values that are derived or computed and are not decommutated directly from the telemetry stream. The FOT must enter all pseudos into the PDB.

c. Discrete Telemetry Color Assignments. The color associated with the display of a discrete telemetry point is determined by it's expected nominal values. Since the nominal configuration or values may differ between the I&T and on-orbit environment, FOT editing of this information is required. The FOT will ensure proper color assignments consistent with anticipated on-orbit configurations.

d. Command End-Item Telemetry Verifiers. I&T delivery of the PDB does not include this information. All command end-item telemetry verification information must be entered by the FOT.

e. Critical Command Definitions. The PDB received from I&T will have critical command flags set. However, the FOT is required to review all critical commands with the appropriate subsystem engineers to ensure completeness and that commands flagged as critical are appropriate for on-orbit operations.



Note: Table inputs will be received from SDVF via the OST workstation.

Figure 7.5-1 Project DataBase Distribution

7.5.6 PDB Editor

The MOC provides a means to access and edit the PDB through the Oracle relational DataBase management system. Oracle, a commercial off-the-shelf (COTS) package, will allow for the safe reception, validation, editing, and maintenance of the PDB. It will provide data base generation to operational status as well as provisions for file generation to other users as well as various reports and listings. An archival/retrieval capability is also provided.

Oracle provides for a variety of reports. As the FOT takes over maintenance of the PDB after launch, hard copy reports to supplement the Telemetry & Command Handbook will be generated.

7.5.7 Operations Handbook

An additional MOC capability includes the development of an on-line TRMM Operations Handbook. The approach to the Operations Handbook involves the use of Oracle for report and display options, and access to the PDB files for all telemetry and command information. In addition, ancillary files provided by Code 700 which describe other pertinent operations information will be incorporated. These ancillary files will include information such as command constraints, power-up default states for telemetry parameters, contingency procedures, engineering points-of-contact, and other appropriate information not included in the PDB.

Oracle provided displays reflecting specified telemetry or command mnemonic information will be accessible from any MOC workstation in an FOT-suggested format exclusively for this operational guide. In addition, a variety of hard copy printout options are also supported.

7.6 DATA ARCHIVAL

Receiving and logging of all real-time and recorded housekeeping telemetry data will cause the file allocations on the FEP to saturate at some point in the work day. This will be avoided by periodically swapping the connectivity to the front ends (between TDRS supports). In this manner, the data history files can be archived and the FEP memory allocation freed. The operational concept is for a front end to support 24-hours worth of real-time activity before giving way to the second FEP for the next twenty-four hours of service. After each support, all telemetry frames and event message Delogs will be transferred from the FEP to a dedicated Workstation (WS). At the end of each shift (8-hours), the analysts will transfer the data from the WS to a 4 mm tape.